Disruption to Transportation Systems caused by Abandoned Mine Workings

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Scope

- History of mining in UK
- Effect of mining on Transportation Systems
- Bridge design for mining subsidence
- Reactivation of old mine workings
- Case History
- Alternative design solutions

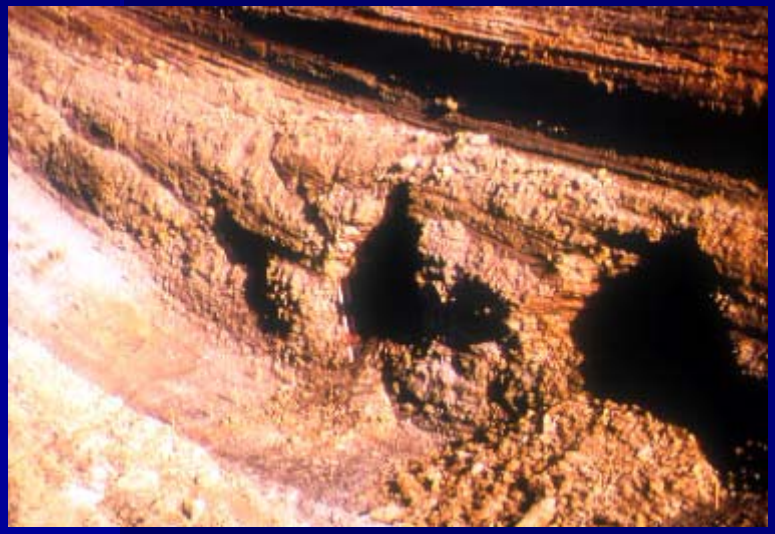
History of Mining in UK

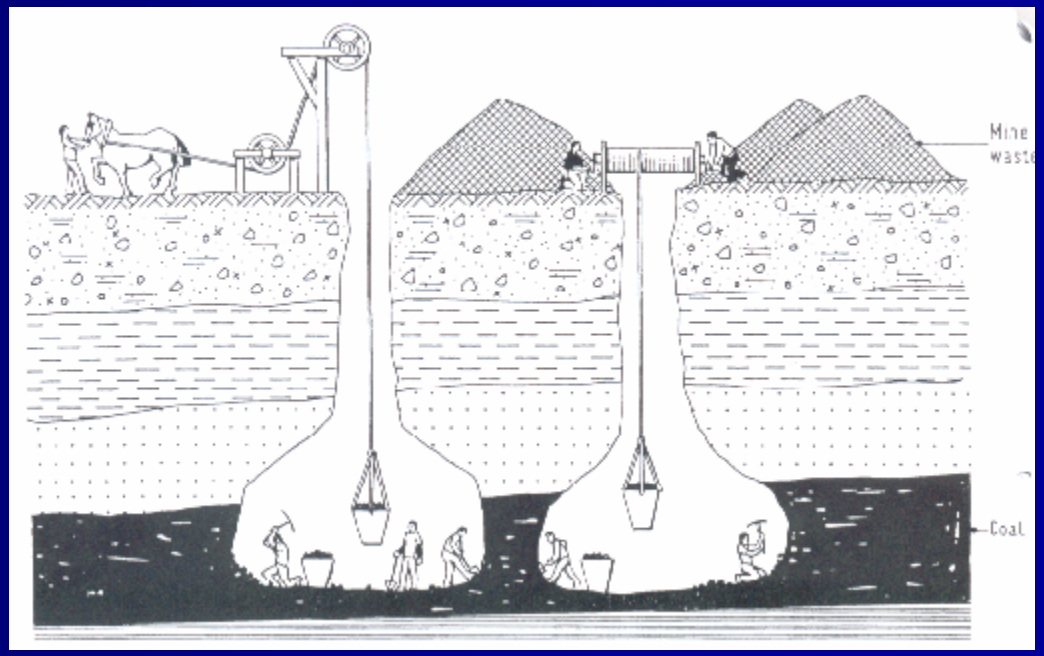
- Romans mined coal, lead, tin and copper (55BC-440AD)
- First licence to mine for coal issued in Newcastle in 1215
- Industrial Revolution: UK world supplier of lead, copper, and coal
- Coal production peaked at 292Mt in 1913

- **Up to 25% of UK land mass undermine**

Old mining methods

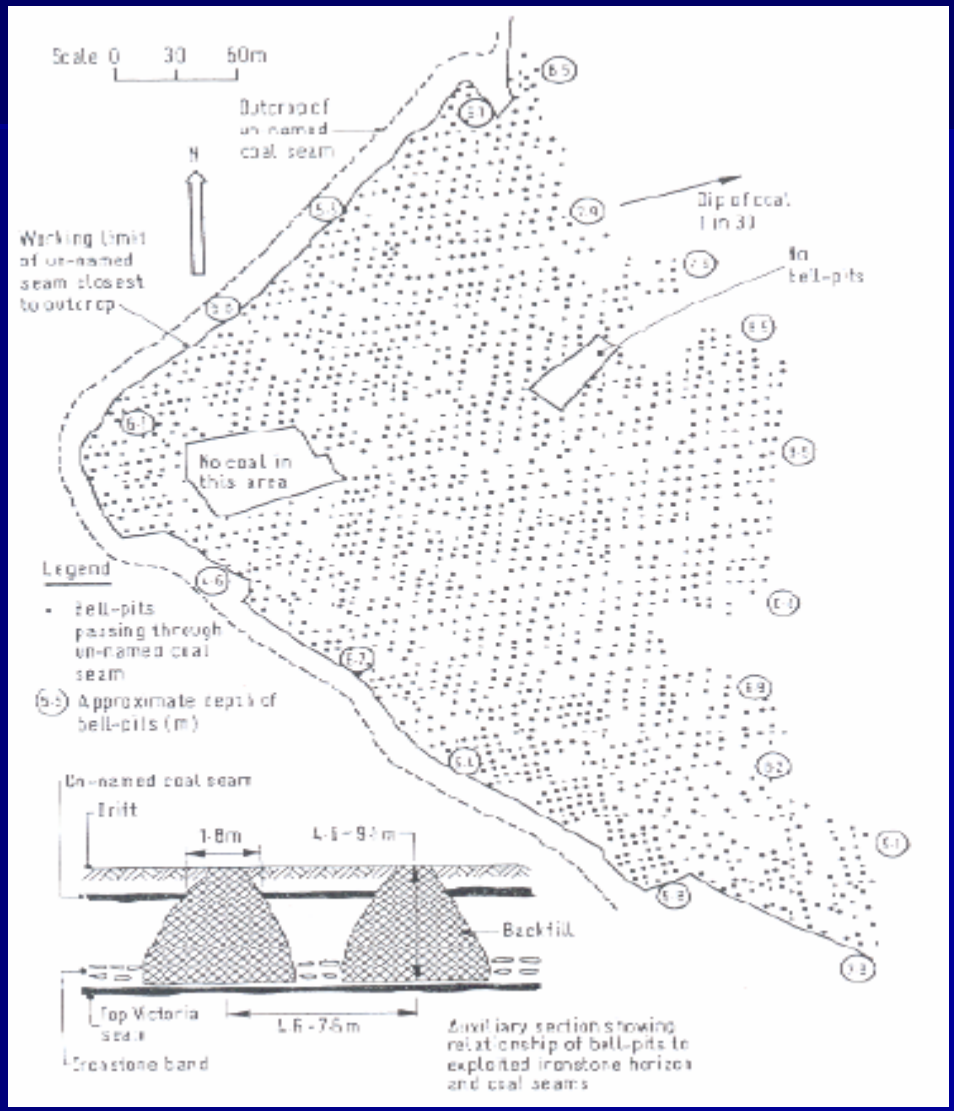
- Bell pits





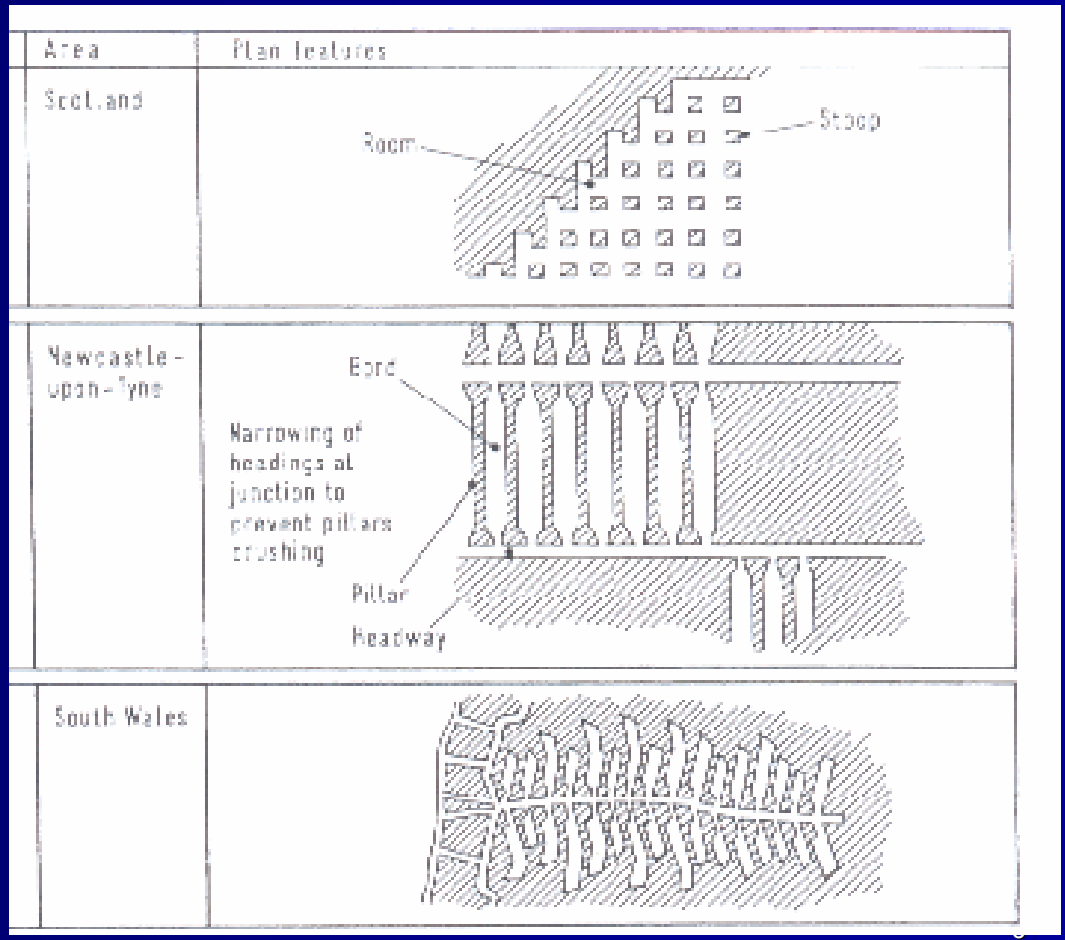
Old mining methods

- Bell pits
- Maximum depth 10m



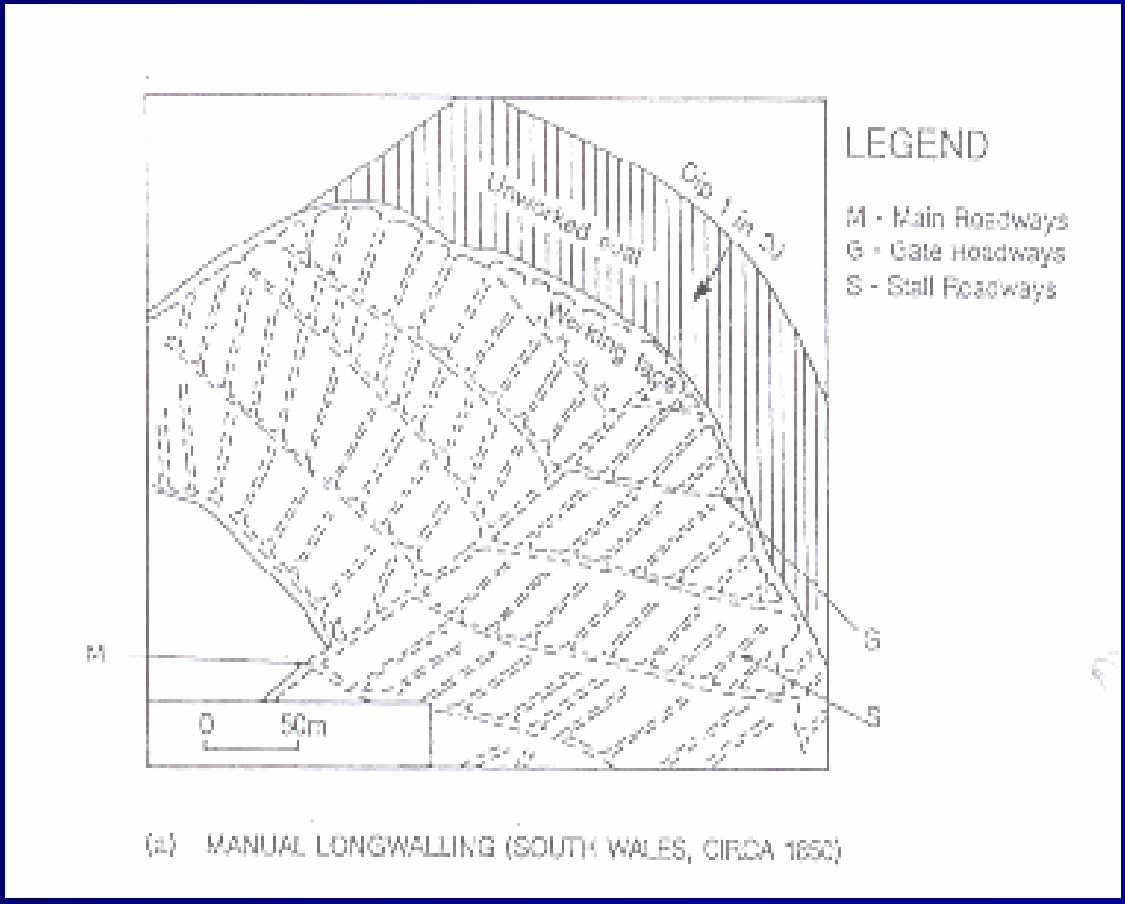
Old mining methods

Mine shafts and pillar and stall workings 13thC



Old mining methods

Long wall mining (invention of steam engine permitted development of deep mines)



(a) MANUAL LONGWALLING (SOUTH WALES, CIRCA 1850)

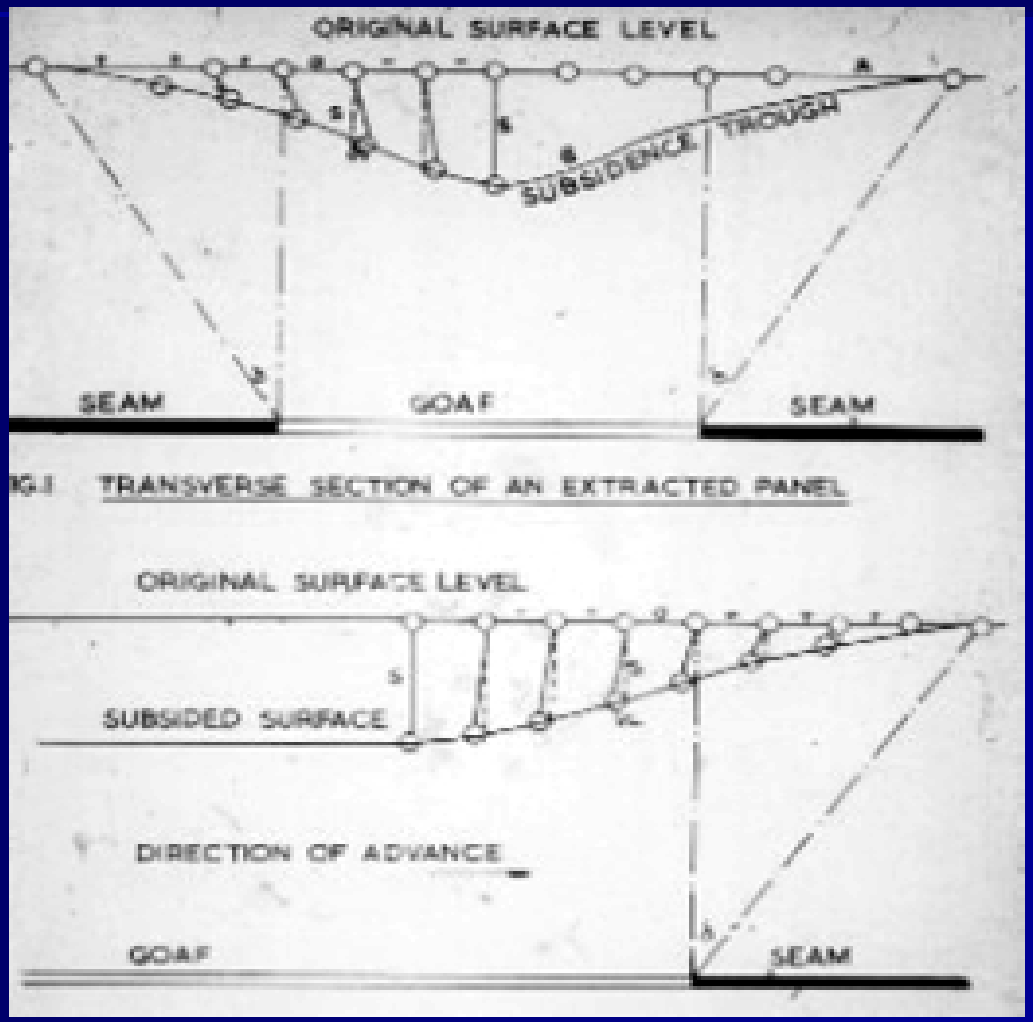
Effect of mining on Transportation Systems

Collapse of old workings
Norwich 1988

Effect of mining on Transportation Systems

Long wall workings Yorkshire 1980s

Effect of mining on Transportation Systems



Effect of mining on Transportation Systems

Design of bridges to cater for mining subsidence

Bridges subjected to 11 components of movement
Dual 3 lane bridge:

- Differential settlement of 600mm
- Change in span length of up to 300mm
- Twist of deck of 1 in 20

Design of bridges to cater for mining subsidence

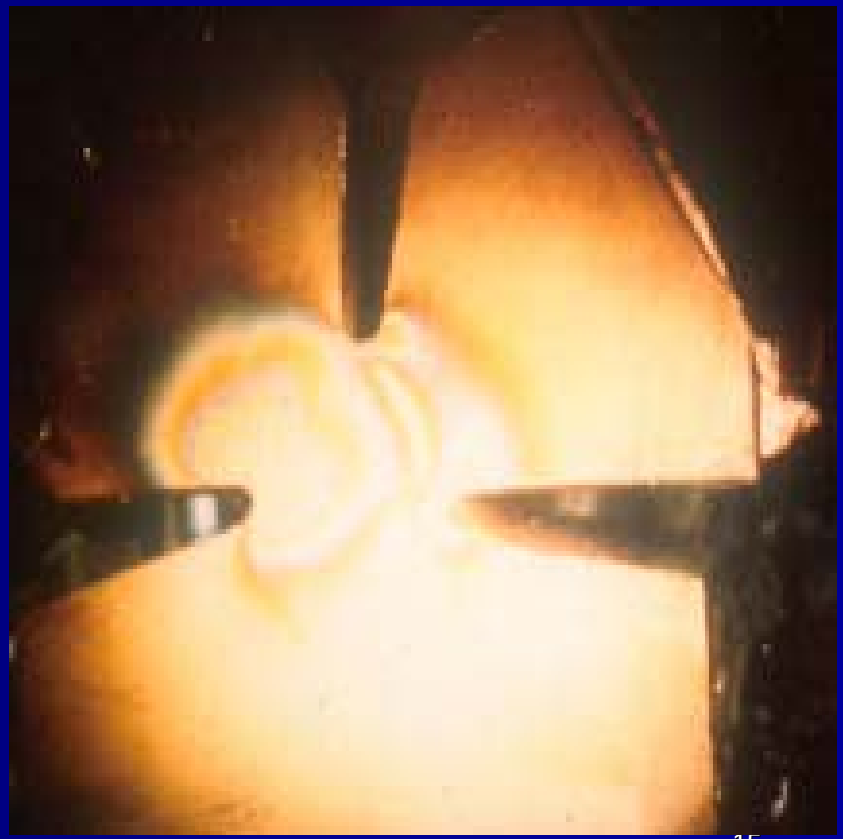
3D statically determinate structures
(supported on 3 bearings)

Design of bridges to cater for mining subsidence

Wichert truss foot bridge using concrete bearings

Design of bridges to cater for mining subsidence

Load test



Reactivation of Subsidence from old Workings and Collapse of Shafts

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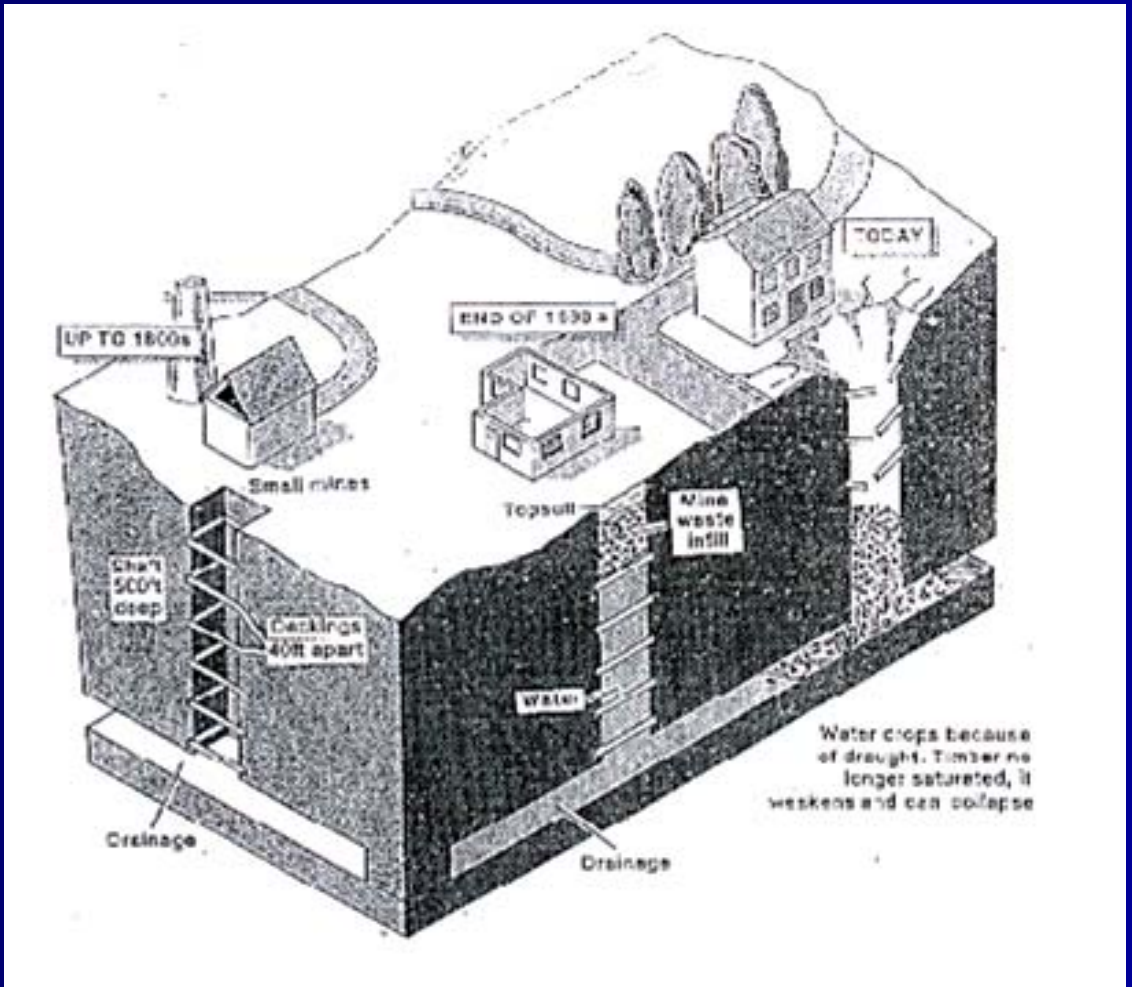


Reactivation of Subsidence: Examples

South Wales 30-40 events per year
- 15% cause damage to roads
- Crown holes 44%
- Shaft collapse 19%
- Adit collapse 34%

Cornwall
- 1000+Shafts
- 20-30 events per year

Derbyshire
- 20000-200000 Shafts (2300 capped)

Scotland
- General failure due to pillar collapse

Causes of Reactivation of Subsidence from old Workings

Degradation of pillars leading to collapse

Rising water table due to abandonment of pumping following mine closure

Degradation of shaft capping system

Long term migration of voids

Excavation towards old workings (construction in cutting)

Causes of Reactivation of Subsidence

Excavation towards old workings (construction in cutting)

Case History: East Coast Main Railway between Edinburgh and London

In 2001 Sink holes 1-3m in diameter appeared either side of the ECML south of Edinburgh

Historical records showed;

- A history of mining subsidence during 1800s and early 1900s
- 4 shallow seams worked between 1700-1870
- The presence of at least 3 shafts near the track

Case History: ECML

Speed of trains immediately reduced to 20mph (from 125mph)

Remote sensing could not detect or predict where the voids were before they appeared on the surface

All attempts to locate the mine shafts using remote sensing failed

ECML Remedial Works

Design Options:

1.Temporary diversion of track, stabilize embankment and reinstate on original line

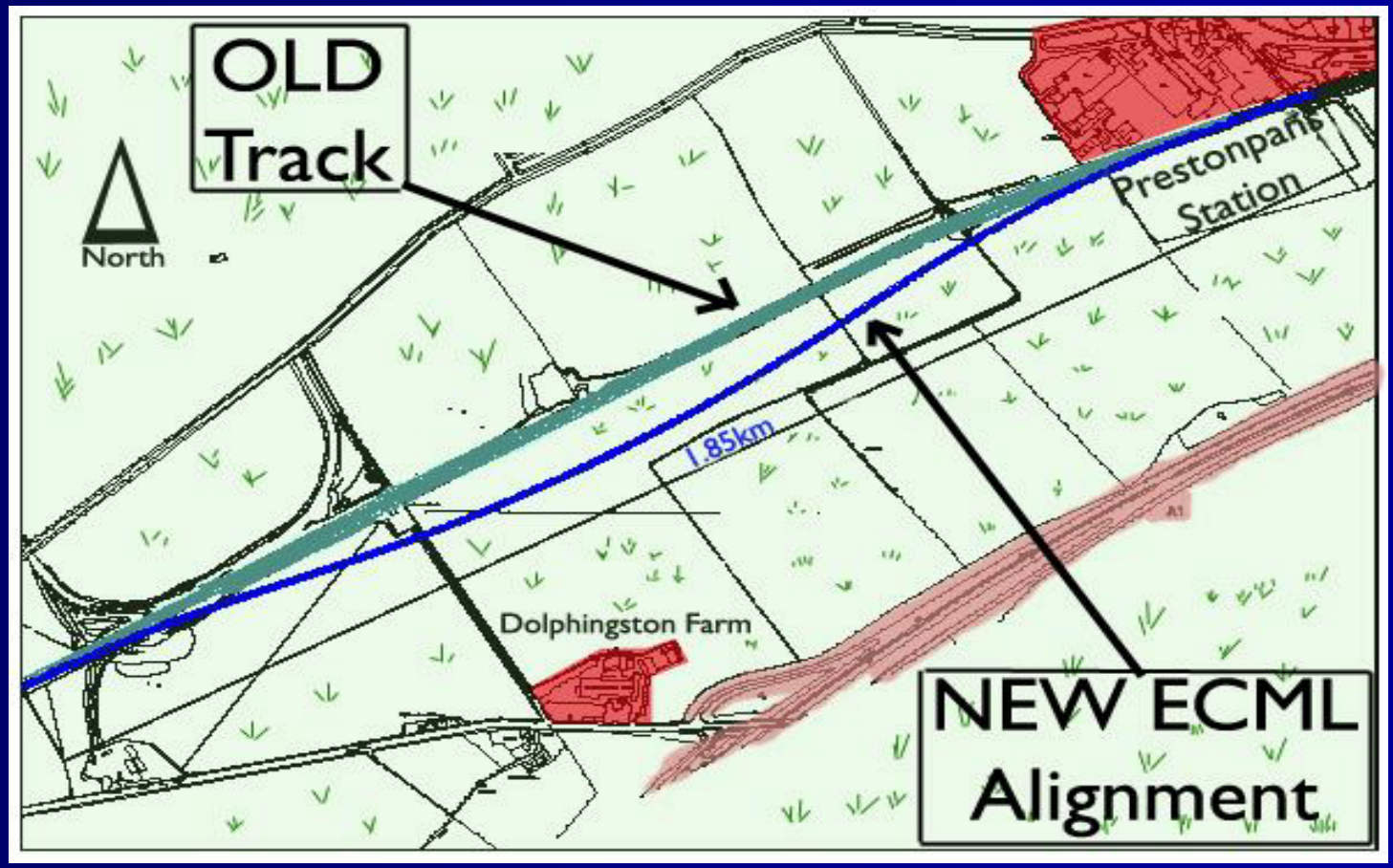
2. Permanent diversion of track

3. Repair by Grouting of voids and construction of concrete raft supported on piles passing below coal seams (Walk away solution)

4.Use high strength geotextiles to reinforce the embankment and provide permanent monitoring

Options 2and 3 were selected

ECML


OLD
Track
North
Prestonpans
Station
1 85km
A1
Dolphingston Farm
NEW ECML
Alignment

ECML Conclusions

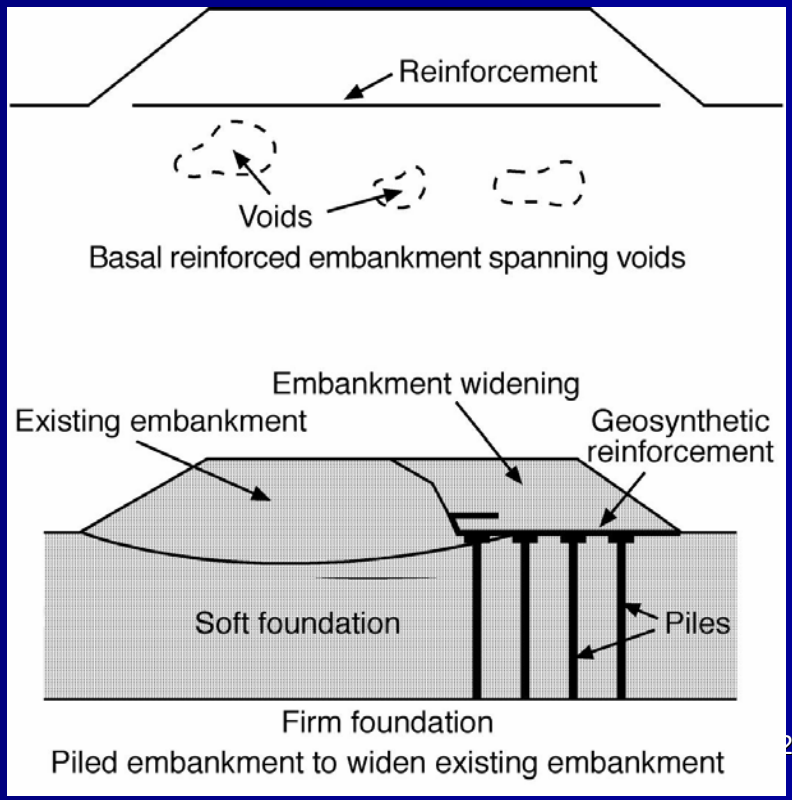
Current methods to detect subsurface voids are inadequate

Less expensive methods to stabilize embankments and track are required (ECML repair cost **£58m**)

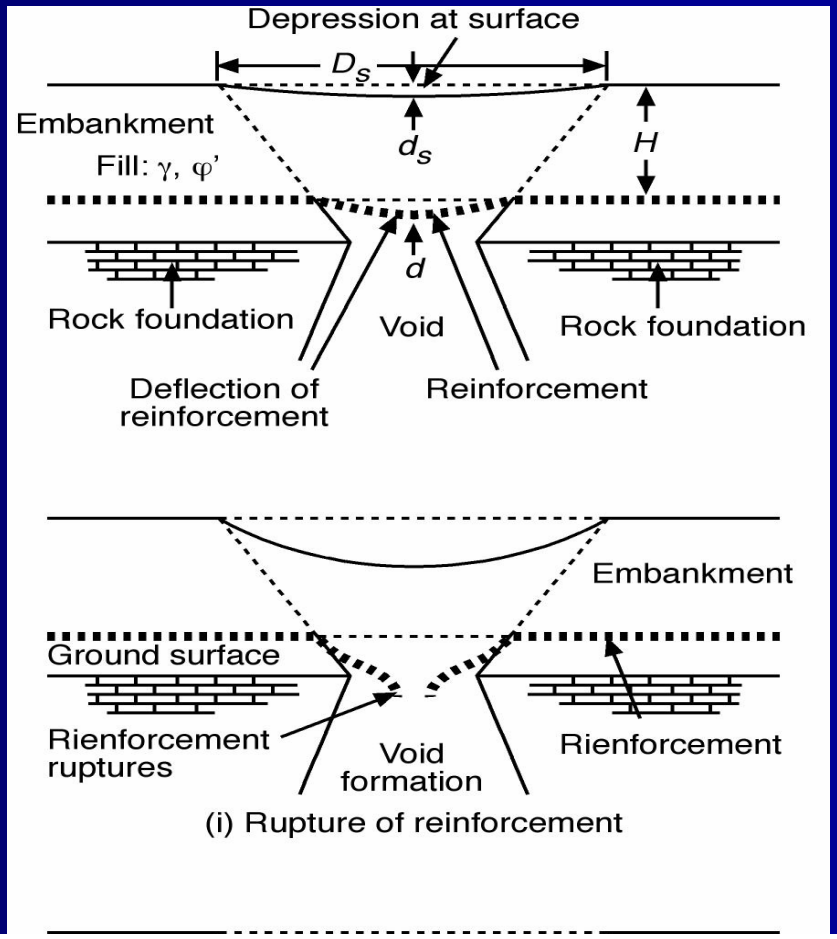
The reactivation of old mining subsidence is a major problem

ECML Alternative Remedial Methods

Geosynthetic Reinforcement spanning the voids
Geosynthetic Piled Embankment
Modern form of “Logging”



Alternative Remedial Methods



Geosynthetic Reinforcement Spanning Voids

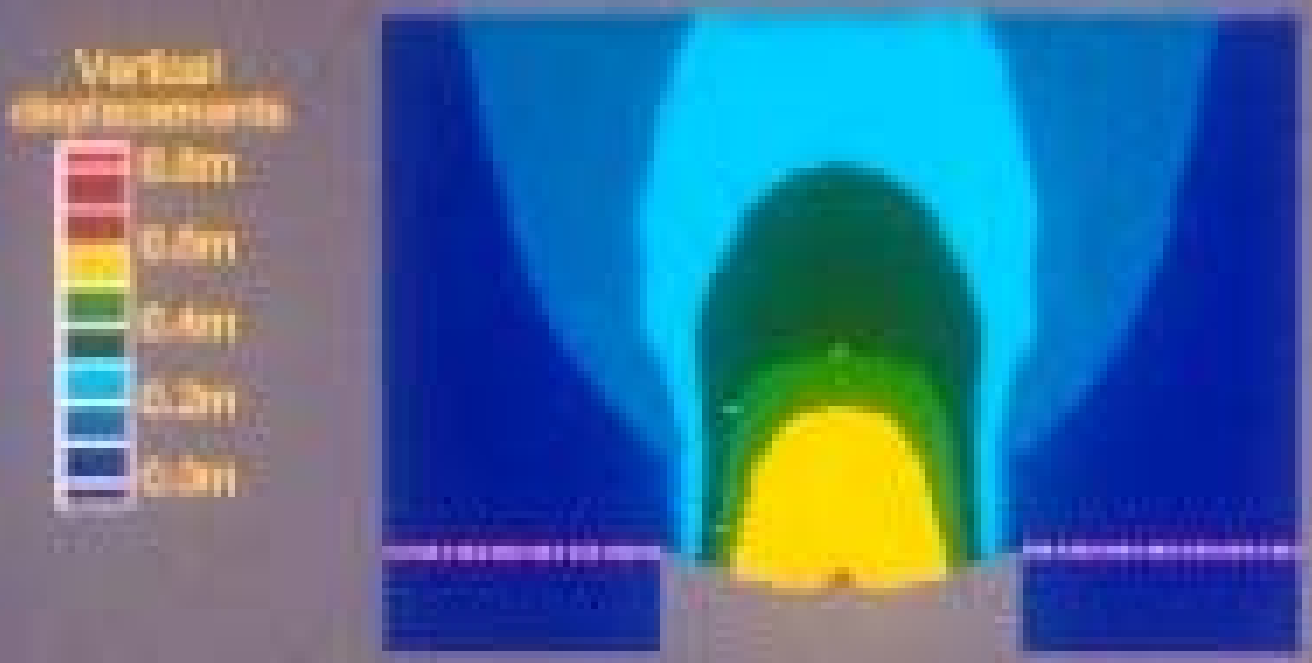
System Limits

Minor roads	d/D <1 in 50
Motorways	d/D <1 in 100
Railways	d/D <1 in 500

Vertical Displacement Characteristics

Rock foundation, d = 4m, H = 10m

D_v/s_i = 1.1%



Granular fill:
γ = 20kN/m³
ϕ' = 35°
c' = 0

Reinforcement:
J = 2,000kN/m

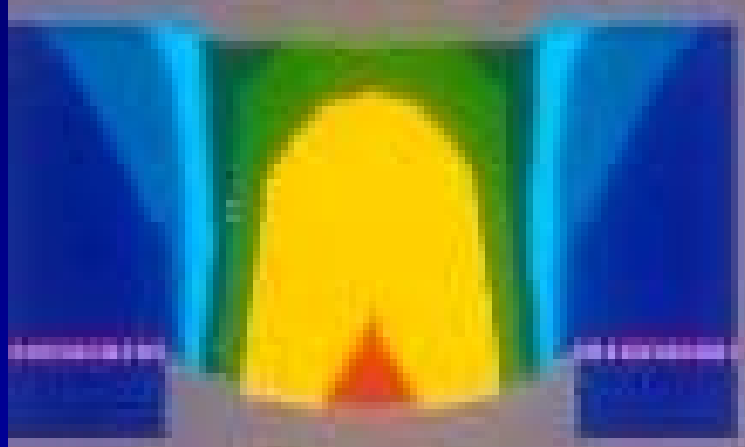
Rock foundation:
γ = 24kN/m³
ϕ' = 42°
c' = 7,000kN/m²
T = 2,000 kN/m²

Effect of Reinforcement Stiffness

Rock foundation, $d = 4m$, $H = 4m$

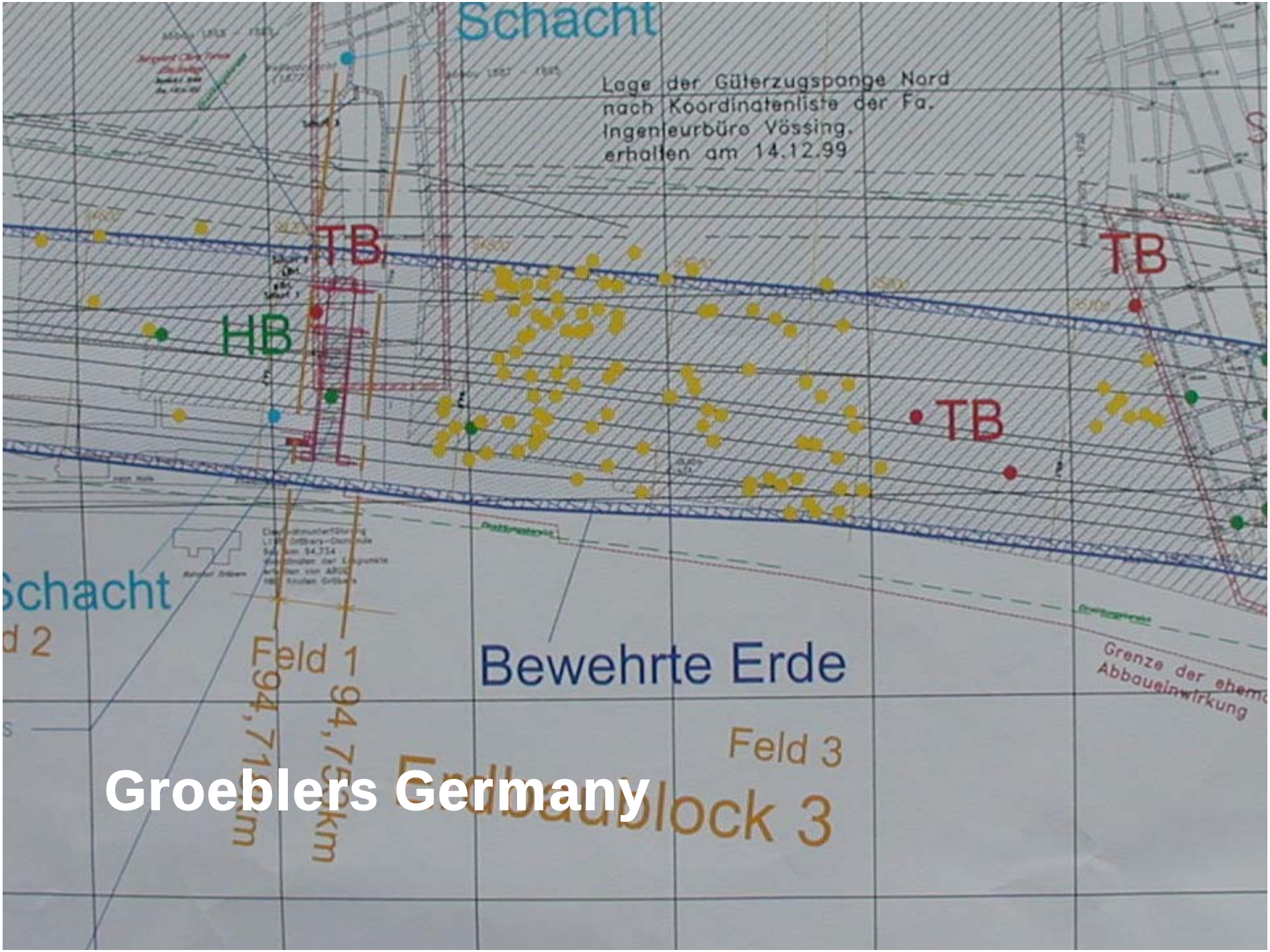
Reinforcement stiffness = 2,000kN/m

D/L_f = 3.7%



Reinforcement stiffness = 12,000kN/m

D/L_f = 2.0%


Schacht
Lage der Güterzugsponge Nord
nach Koordinatenliste der Fa.
Ingenieurbüro Vössing,
erhalten am 14.12.99
TB
HB
TB
TB
Schacht
d 2
Feld 1
94,775km
94,750km
Bewehrte Erde
Feld 3
Endbaublock 3
Grenze der ehem
Abbaueinwirkung
Groeblers Germany


HUESKER
HUESKER

Groebers Solution

Requires **permanent** monitoring

Remedial work still needed

Alternative Remedial Methods

Geosynthetic Piled Embankment (as at Stansted, London)

Alternative Remedial Methods

Modern form of “Logging”

Conclusions

Reactivation of mining subsidence from old workings poses a major problem

Current remedial methods are either expensive or require long term commitment to sophisticated monitoring

A modern form of “logging” may be a solution